LM-2

Digital Air/Fuel Ratio Meter
User Manual

Warning!

The Oxygen Sensor used in this device gets very hot in operation.
Do not touch the hot sensor. Do not let a hot sensor touch a combustible surface. Do not use the sensor with or near flammable liquids or gases. Failure to heed these warnings may result in severe burns, explosions or fires.

When installed in the exhaust, the oxygen sensor MUST be connected and operating with the LM-2 whenever the car is running. An un-powered oxygen sensor will be quickly damaged when exposed to hot exhaust gases.

TABLE OF CONTENT

1 LM-2 3
1.1 Main Screen 4
1.2 Status Bar 5
1.3 Configuration Menu Screen 7
1.4 Recording 7
2 Air/Fuel Ratio Setup 8
2.1 Sensor Calibration 8
2.2 Sensor Placement 9
2.3 Calibration Schedule 11
3 OBD-II 11
3.1 Locate the OBD-II Connector in your vehicle 11
3.2 Selecting Channels on the LM-2 12
3.3 Selecting Channels with the LM Programmer software 12
3.4 OBD-II Channel Speed 13
3.5 Set the Priority of OBD-II Inputs (Optional) 16
3.6 Check and Clean Vehicle trouble Codes on the LM-2 20
3.7 Check and Clear Vehicle Trouble Codes with LM Programmer 20
3.8 OBD II Basics 21
4 Analog Cable 22
4.1. Programming the analog outputs 23
5 Tips, Tricks, & Trouble Shooting 25
5.1 Air/Fuel and Lambda 25
5.2 General measurement requirements 25
5.3 Vehicles with ‘smog-pumps’ 26
5.4 Single Cylinder Engines 26
5.5 Diesel Engines 26
5.6 Sensor Timing Errors 26
5.7 Connecting the LM-2 to simulate a narrow band oxygen sensor. 27
Appendix A: Specifications 28
Appendix B: Limited Warranty 29
Appendix C: Connectors 29
Appendix D: Supported PIDs 31
Appendix E: Error Codes and Troubleshooting Tips 34
6 Revision History 36

1 LM-2

The LM-2 is a single or dual channel wideband controller with a built-in OBD II scan tool, RPM input, four analog inputs, MTS serial I/O, SD memory card recording and two analog outputs per wideband channel. The following screens will help you get familiar with the unit.

Front

Mode Button
Press once to cycle through channel display screens. Press and hold to enter menu.

Cancel Button
Press to cancel out of menu or to stop recording.

Record
Press once to record or press again to stop recording. Press and hold to force a new log.

LCD Display

Up Arrow
Scroll through available channels. Move through menu

Enter
Accept an entry in the menu screen.

Down Arrow
Scroll through available channels. Move through menu

Left

Inductive Clamp **MTS Serial IN** **MTS Serial OUT**

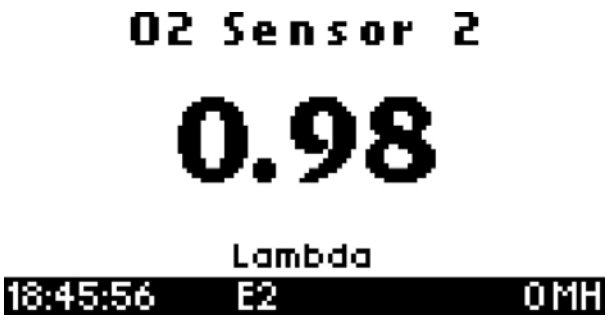
Top

Analog

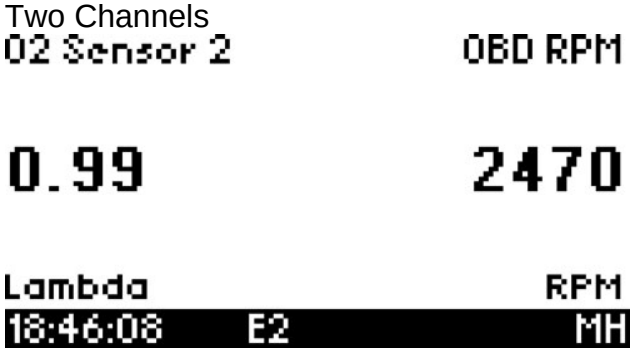
1.1 Main Screen

There are 5 different screen view options. These can be cycled by pressing the Mode button.

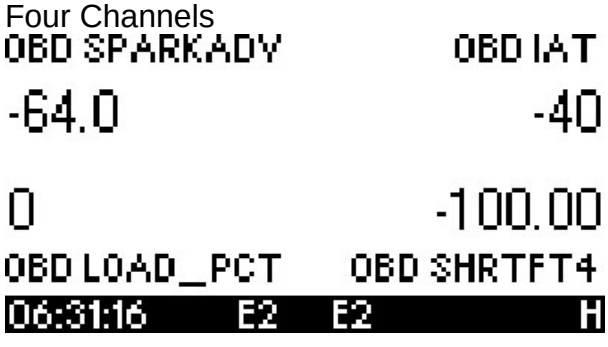
One Channel



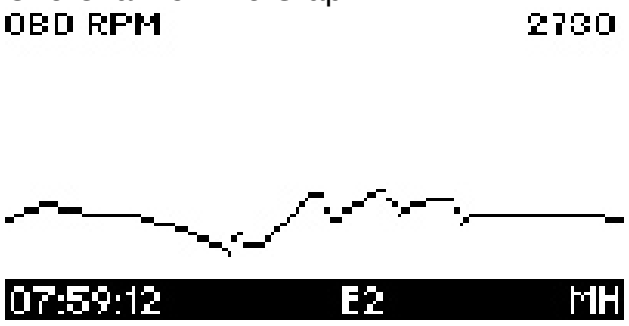
Two Channels



Four Channels



One Channel Line Graph

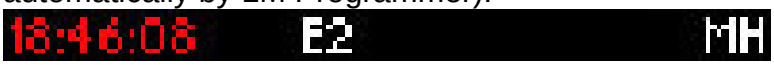


One Channel Fill Graph

1.2 Status Bar

The bottom edge of the screen is the status bar and will look something like this:

The left most portion is the current time (which can be set via menu and is set automatically by LM Programmer).



During Recording, an upper case ‘R’ and a counter will display on the lower left:

Counting minutes and seconds of recording.

Similarly, during playback a upper case ‘P’ and a counter will display:

Counting elapsed time during playback.

Note: If Recording does not start (see later section), also look here, the word “Card?” will appear if no SD card is detected when Record is selected. The word “Full!” will appear if you have either filled the SD card, or exhausted the available log names (see section on recording).

Moving to the right, the next two indications are O2 sensor status, which can be one of the following:

HW - Heater Warm-up
Cal - Calibrating
O2 - Reading O2 context (lambda over 8.something)
L - Reading Lambda (or AFR)
Ex - Error, Check Appendix E for error code meanings and trouble shooting tips

Note: If the LM-2 is a single channel model, the second indication will be blank, not an error code.

The next indicator, “R”, will appear when a) RPM is selected for logging/use (see menus) and b) an RPM signal is detected. Note, when RPM is enabled, but no RPM signal is detected, this symbol will appear in lower case (“r”).

The “A” indicator means that the 4 Analog Inputs are selected for logging/Use (see menus). It is all or nothing. The display will be blank if disabled.

The “O” indicates that an OBD-II connection is active. This indicator will blink at the relative ‘sample rate’, which will vary on the number of channels selected and the vehicle’s protocol. The display will be blank if the unit is not connected to an OBD-II port.

The blinking “M” indicates that MTS serial data is being generated. This will blink at the relative MTS packet rate (for comparison with the O indicator). If the unit is not the “head” unit, then this will only blink when packets are being received via the Serial In connector.

Last, “H” indicates that the unit is the MTS head unit. If the unit is not head this indicator will appear as a “-“

1.3 Configuration Menu Screen

To enter the Configuration Menu Screen press and hold the **Mode** button.

Navigating the Menu:

"**Enter**" Accepts
"**Cancel**" Returns one menu level
"**Mode**" Returns to Main Screen
Arrows adjust selection or value
"**Record**" has no effect

When "Mode" is first pressed, the following choices appear:

- Display AFR or Lambda. *The factory default setting is Lambda*
- Calibrate - Free Air Calibrate ALL O2 sensors connected will be calibrated
- RPM – Enable/Disable RPM
- Analog - Enable/Disable Analog Inputs
    - OBD-II - Configure Number of Channels (0-16), Channel Use, Get/Clear DTC codes and (S*elections do not filter based on current connection. If a certain channel is not available, the data will read 0*)
- Date/Time - Set the current date/time

Important Note: Entering the Configuration Menus will stop recording and suspend MTS packet output

1.4 Recording

When recording is first activated, a file is created. The naming convention is:

mmddyyXX.d32

Basically the month, day, and year that the file is created. The XX is to accommodate multiple files on the same day (counting begins at "00").

Once a file exists, sessions are appended to it for each additional recording. The exceptions to this are:

1. The MTS channel count/type has changed
2. The user requests a new log file by pressing and holding “Record” (or holding the record button on an external XD-16.)

The first instance will occur if devices are added or removed the MTS serial chain , or if channels are enabled/disabled on the LM-2.

When a new file is created, it will be given the day’s date and a unique counter:

07010800.d32
07010801.d32
Etc

2 Air/Fuel Ratio Setup

Innovate Motorsports’ ‘Direct Digital’ wideband measurement principal allows you to calibrate the sensor to compensate for sensor wear. This procedure takes no more than a couple seconds and it will insure the most accurate readings throughout the oxygen sensor’s life.

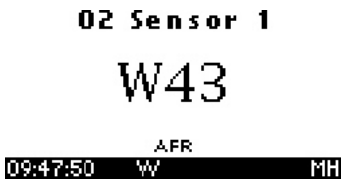
2.1 Sensor Calibration

The calibration procedure requires that the oxygen sensor be in free air, not in the exhaust.

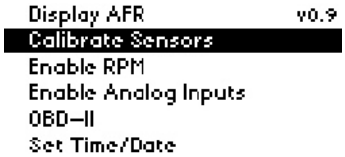
1. Connect the oxygen sensor to the provided sensor cable and then to the appropriate port on the LM-2. **Note**: The dual channel LM-2 model allows you to connect both oxygen sensors to the unit at the same time to do the calibration simultaneously.

2. Connect the LM-2 to the cigarette power plug with the provided cigarette power adapter.

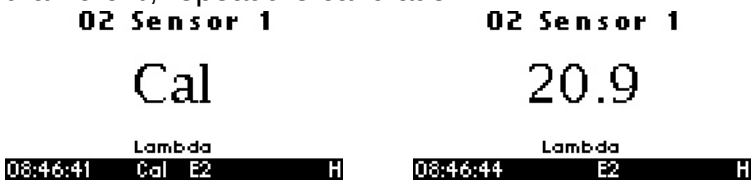
3. The sensor(s) will start warming up. The LM-2 will display WXX, where XX is the percentage of temperature reached. Notice the status bar displaying a ‘W’.



4. Next is the calibration procedure. Press and hold the **Mode** button until the Configuration Menu appears. Select ‘Calibrate Sensors’ and press the **Enter** button.



5. The display will momentarily display ‘Cal’ and then it will switch to reading a percentage of oxygen. If the oxygen content now differs from 20.9% by more than 0.6%, repeat the calibration.



6. The LM-2 is calibrated and ready for use.

The LM-2 must be powered by the cigarette adapter (12 volts) in order to properly heat the Oxygen sensor and measure Air/Fuel. If the unit is only to be used connected to the OBDII port it will properly function as a scan tool.

2.2 Sensor Placement

Using a bung is the preferred method for mounting the O^2 sensor for both catalytic and non-catalytic cars.

On CATALYTIC CONVERTER equipped vehicles:

Install the oxygen sensor’s bung upstream from the catalytic converter (a bung and plug is included in the LM-2 kit). The bung must be installed in the exhaust pipe *at the side or on top, NOT on the bottom* of the exhaust pipe. Any decent muffler or exhaust shop can do this for you. The wide-band oxygen sensor is then installed into the bung to take a reading. (Insert the plug into the bung when not in use). The ideal position is between 10:00 and 2:00 position.

On NON-CATALYTIC converter vehicles:

You have the option with non-catalytic cars to also use an exhaust clamp as described below. Use of a bung is the preferred method for mounting the 0^2 sensor for both catalytic and non-catalytic cars.

On TURBO CHARGED vehicles:

Install the bung downstream from the turbo but before the catalytic converter. The high exhaust pressure before the turbo interferes with the lambda measurement and the high exhaust temperatures encountered there can damage the sensor.

Alternatively you can also use the optional exhaust clamp (part number 3728) to sample exhaust gases at the end of the tail pipe.

Do NOT install the Bung below the 3 o'clock or 9 o'clock position. Condensation can form in the exhaust pipe and permanently damage the sensor. 6 o'clock is the absolute worst position to mount the sensor.

Wide band oxygen sensors, like the one shipped with the LM-2, are designed to work with unleaded gasoline. Use with leaded gasoline will significantly reduce the lifespan of the sensor. The reduction is directly proportional to the metal content of the fuel and the tune of the engine. In most cases, a wide band sensor will provide accurate measurements somewhere between 50 hours and 500 hours with leaded fuel.

WHEN INSTALLED IN THE EXHAUST, THE OXYGEN SENSOR MUST BE CONNECTED AND OPERATING WITH THE LM-2 WHENEVER THE CAR IS RUNNING. AN UN-POWERED OXYGEN SENSOR WILL BE DAMAGED WHEN EXPOSED TO EXHAUST GAS IF NOT PROPERLY POWERED.

The maximum temperature of the sensor at the bung (the sensor hexagon) should not exceed 500 ^{o}C or 900 ^{o}F. If these temperatures are exceeded in your application you should either install a double length bung (one inch) or the Innovate Motorsports Heat-Sink Bung extender (HBX-1).
The double length bung is also recommended for situations where airflow is restricted.

It is NOT a good idea to do a sensor warm-up prior to starting the vehicle. Depending on the climate and the sensor position in the exhaust, condensation can form in the exhaust pipes. This condensation could then be blown by the exhaust stream against the hot sensor when the car is started. The resulting heat shock can permanently damage the sensor.

2.3 Calibration Schedule

Normally aspirated (daily driver)
- Calibrate before installation of new sensor
- Calibrate new sensor again after 3 month of use
- Thereafter calibrate once a year or every 20,000 miles, whichever comes first

Turbo Application, daily driver (tuned rich)
- Calibrate before installation of new sensor
- Calibrate new sensor again after 3 month of use
- Thereafter calibrate twice a year or every 10,000 miles, whichever comes first

Race Application
- Calibrate before first installation of new sensor
- Calibrate once per race weekend
- For added sensor life we also recommend our optional double length bung (part number 3764

Dyno use:
- Calibrate a new sensor
- Calibrate every 2-3 days, depending on usage

3 OBD-II

The LM-2 allows you to read up to 16 channels of "OBD-II" ("On Board Diagnostic) information directly from your vehicle's engine control unit (ECU). A log file can be recorded on the included SD card, and played back on a personal computer using Innovate's LogWorks software (included with the LM-2) or other 3rd party MTS-compatible applications.

3.1 Locate the OBD-II Connector in your vehicle

This is typically the most dangerous aspect of LM-2 installation. A safety helmet is wholly optional, but a flashlight can be extremely helpful. The connector is required to be within 3' of the driver's seat in the vehicle and accessible without tools. Generally it is somewhere just behind the bottom edge of the dashboard, immediately in front of the driver, but it may be in a relatively obscure place, like hidden behind an ashtray.

If you are unable to locate the connector by inspection your best bet would be to either ask a mechanic familiar with the make and model vehicle or locate an online hobbyist/enthusiast group devoted to your vehicle.

Here is a sample OBD-II connector. Please note that the orientation of the connector varies from vehicle to vehicle.

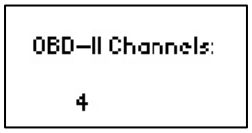
For example, in this example, the wide part of the connector is 'down'. In other installations this wide part of the connector will be up. In still other installations the entire connector may be 'facing' the floorboard.

On many newer vehicles the connector is concealed behind a small door or removable plastic cover plate.

Also, the connector itself may be covered with a small, removable, rubber cap.

3.2 Selecting Channels on the LM-2

1. Press and hold the **Mode** button to go into the Configuration Menu Screen. Select *OBD-II* and press the **Enter** button.
2. Select *Configure OBD-II.*
3. You will now be given the option to select the number of OBD-II channels to log. (A maximum of 16 channels can be selected)



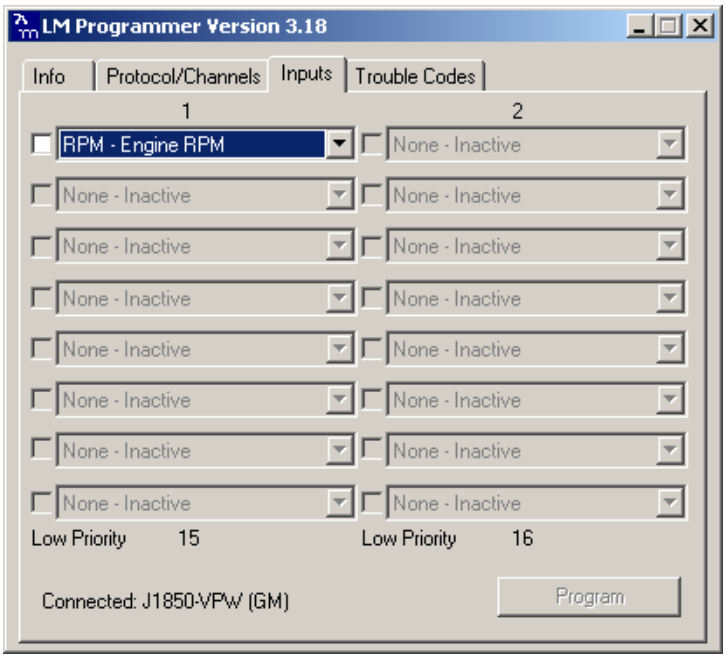
4. You will now be able to scroll through all available channels and make your selections. Press the Enter button to move on to the next channel.
5. The selected channels will now be available to Record or view on the LM-2's display.

If a PID (channel) is not available for the particular vehicle, the data will read 0)

3.3 Selecting Channels with the LM Programmer software

1. Install the CD that came with your LM-2 in your personal computer and load the software.

2. Connect one end of the USB cable to the LM-2 and the other end to your computer.
3. The LM Programmer application can be launched from *Start->Programs->LogWorks2->LM Programmer* from the Windows task bar. A small dialog box will appear indicating that the program is looking for connected Innovate Devices, then the main dialog should appear.
4. The Channels tab allows you to set the number of MTS channels to generate.
5. Click the Inputs tab. Only the number of channels selected on the Protocol/Channels page can be edited. The available values for logging on the connected ECU are listed in the drop list for each Input. Some vehicles will support larger lists than others.

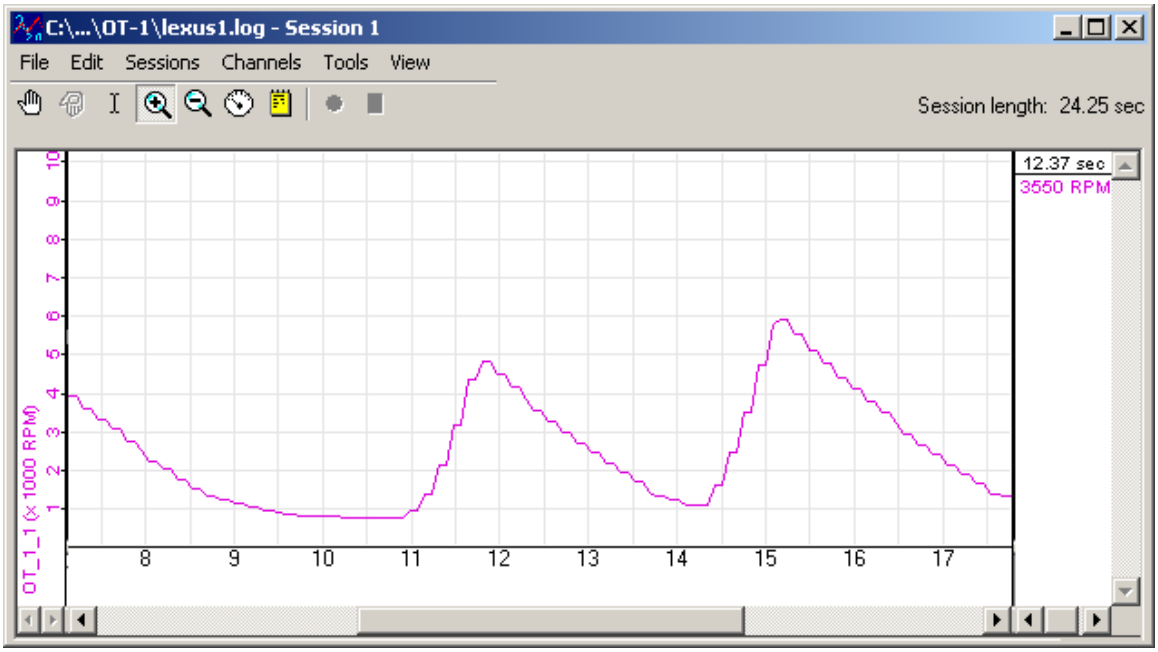


6. Hit the 'Program' button to send the configuration.

Also, it cannot be stressed enough that different ECUs will have dramatically different response speeds. Here are two extreme examples.

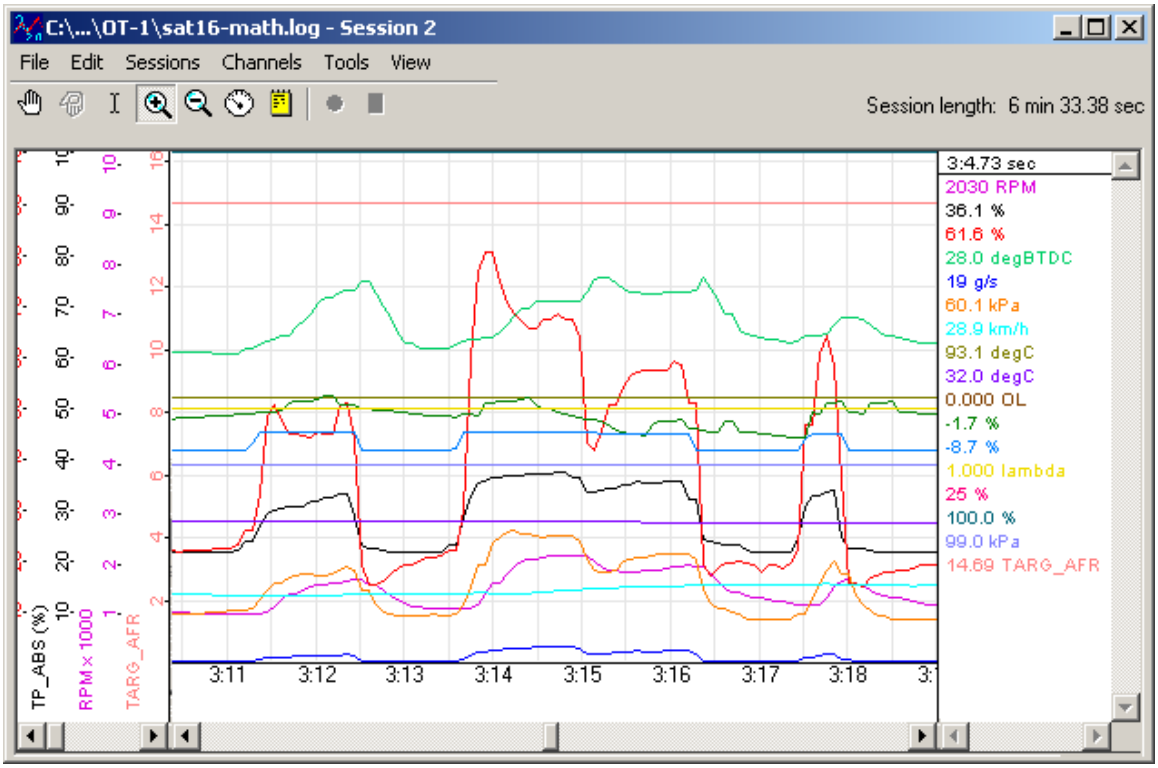
3.4 OBD-II Channel Speed

The first is a log trace of one channel (RPM) from a 2001 Lexus:


C:\...\OT-1\lexus1.log - Session 1
File Edit Sessions Channels Tools View
Session length: 24.25 sec
12.37 sec
3550 RPM
OT_1_1 (x 1000 RPM)
8 9 10 11 12 13 14 15 16 17

Notice that the data appears ‘steppy’ and, based on the timeline, appears to be updating about 6 times per second.

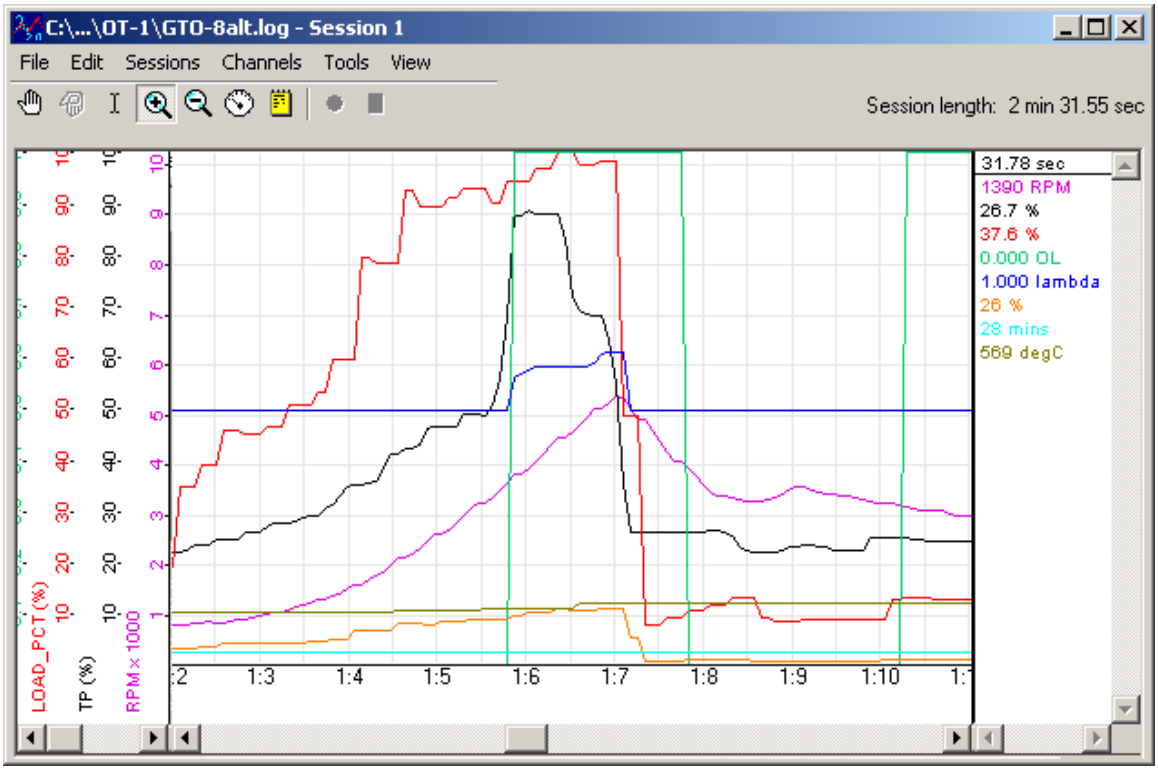
Next we have a log trace of 16 channels (RPM, MAF, MAP, TP, you name it) from a 2006 Saturn:



Even if we zoom in to a closer time scale, the data is quite smooth. Performance is controlled by two things:

- The Connection Speed
- ECU Responsiveness

The Lexus in the first example is using ISO 9141 and 10.4K bits per second. The Saturn is using ISO 15765 (CAN) at 500K bits per second. So it is easy to understand the difference in performance.
However, the responsiveness of the ECU also can be a significant factor. Consider this log from a 2006 Pontiac GTO:



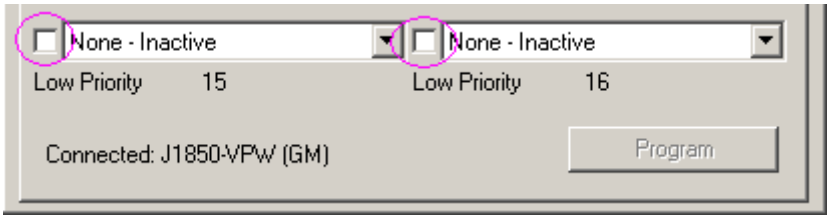
Like the Saturn, it is connected using 500K bit CAN, but we can begin to see some 'steppiness' in the RPM channel with only 8 channels being collected. In addition, some values, like the Calculated Load are courser still. Presumably because the ECU itself is only calculating them a few times per second.

With this in mind, it is probably best to assign channels only a few at a time and then select "Program". The ECU will disconnect, reconnect with the new choices, and then the overall sample rate of the current settings can be observed using the blinking vehicle light on the LM-2.

It is then up to you, the user, to decide what is an acceptable balance.

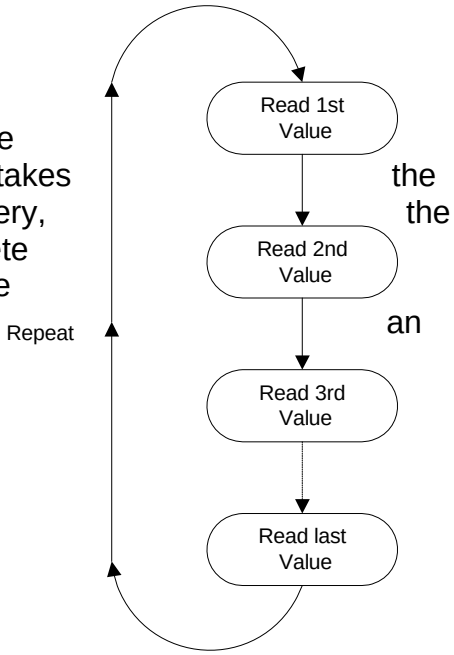
3.5 Set the Priority of OBD-II Inputs (Optional)

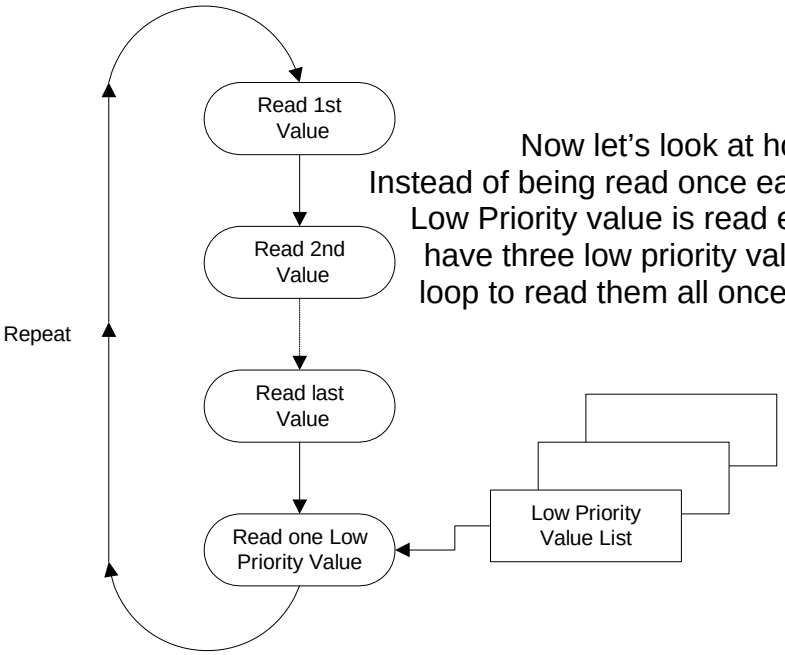
Next to each Input Selection on the Inputs page there is a small checkbox. These checkboxes are labeled “Low Priority”:



Since it is often a battle getting an ECU to deliver data fast enough, it is reasonable to ask why one would lower the priority of a channel? The simple answer is, some ECU values just do not change very fast. So, reading those values less often means that values that do change quickly can be read more often. To understand how this works let’s take a look at how the LM-2 normally reads values:

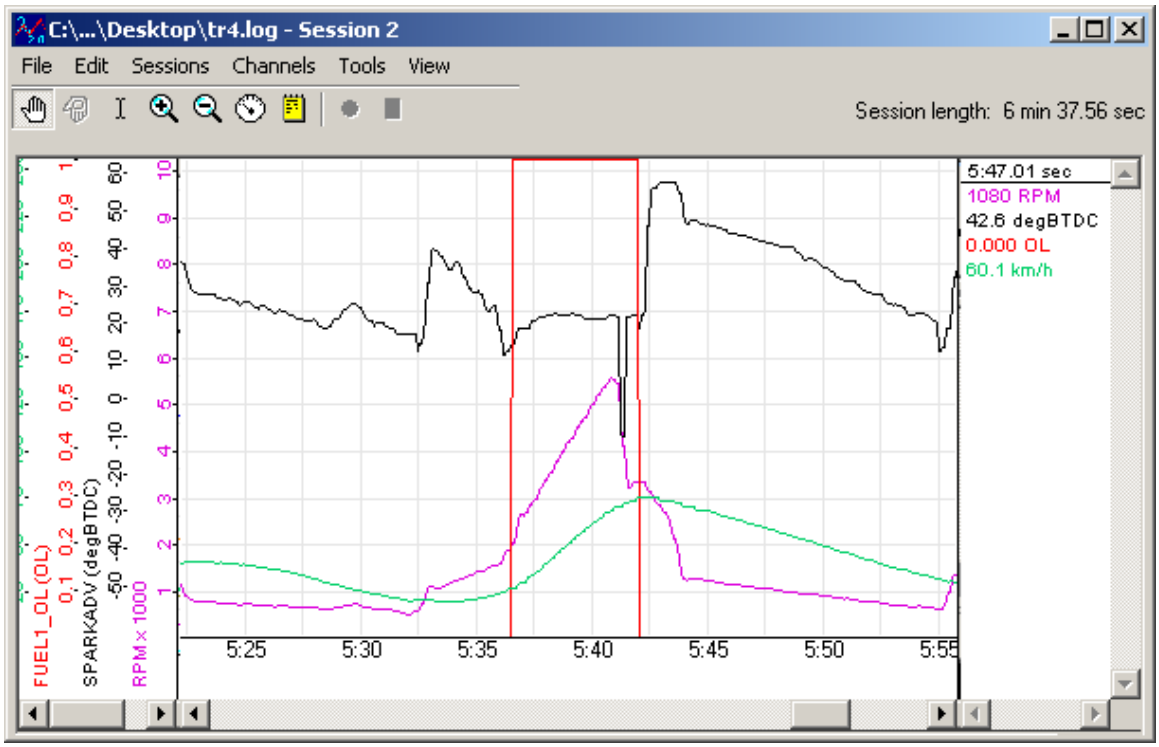
As we can see from the diagram on the right, values are read from the ECU one after another, in a loop. Since takes the ECU has certain amount of time to respond to each query, the longer the list of channels, the longer it takes to complete the loop. Obviously, the longer to takes to complete the loop, the larger the time gap between each read of an individual value.



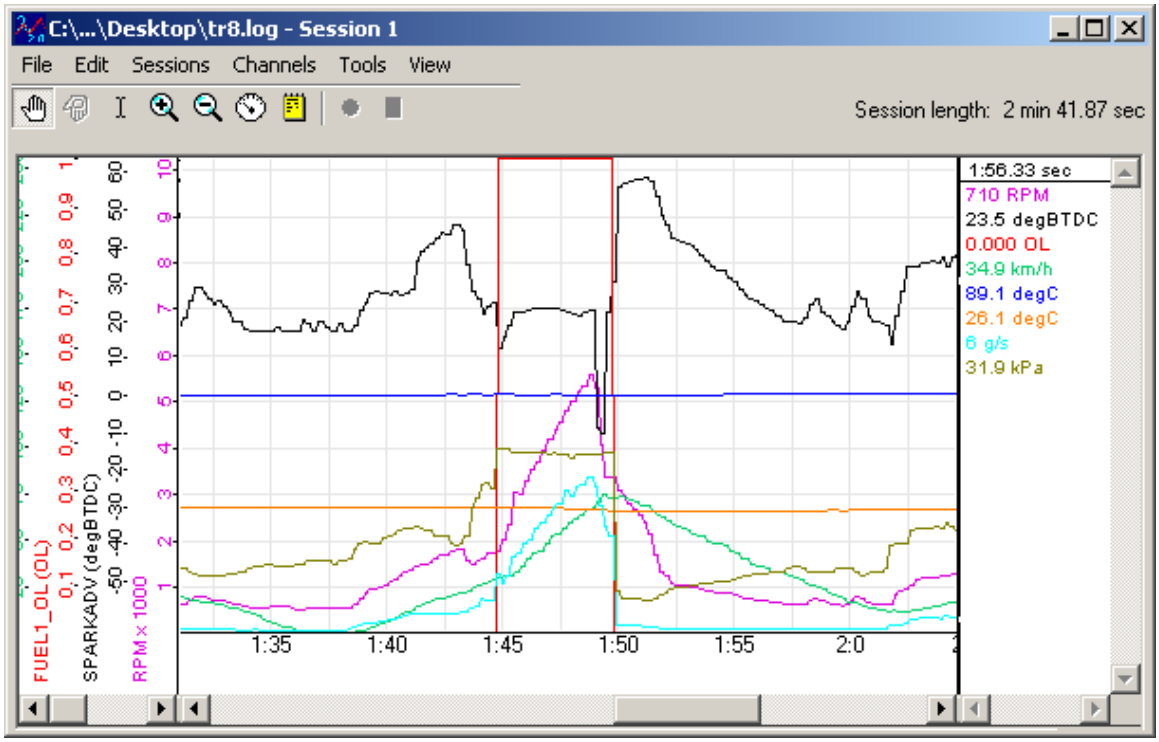


Now let's look at how Low Priority Values fit into this. Instead of being read once each time through the loop, only one Low Priority value is read each time through the loop. So, if you have three low priority values, it will take three passes of the loop to read them all once.

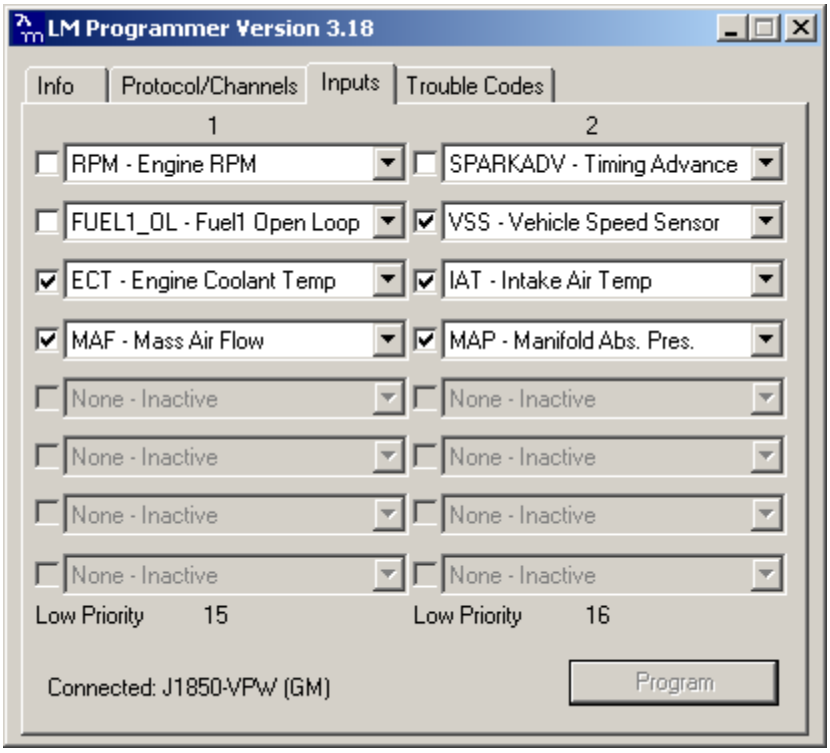
With our racetrack shaped diagram fresh in mind, let's look at Low Priority inputs in practice. In this example the vehicle can provide four LM-2 channels that update at full MTS rates. Even four channels are still very usable. For example, here is RPM, SPARKADV (ignition timing), FUEL1_OL (Open Loop Status) and VSS (Vehicle Speed Sensor):



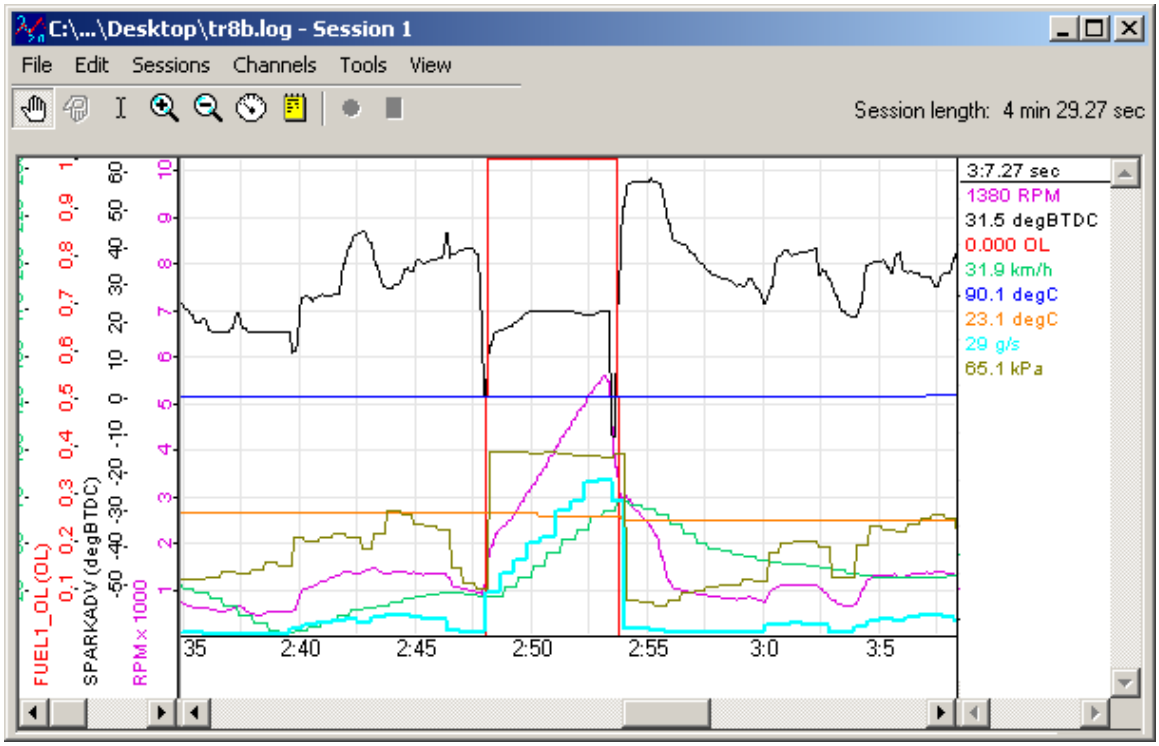
But what would happen if we also added ECT, IAT, MAF, and MAP? If we left all our channels at normal priority, some critical channels may not be fast enough for our purposes:



But not all channels change quickly and we are more concerned with some channels than others. For example, let's say we are primarily concerned with RPM, SPARKADV, and FUEL1_OL. We'd like VSS, IAT, ECT, MAF, and MAP but we do not care if they update slowly. So, we can mark those channels as low priority:



Now, when we log the data, RPM, SPARKADV, and FUEL1_OL, look like our original four channel log:



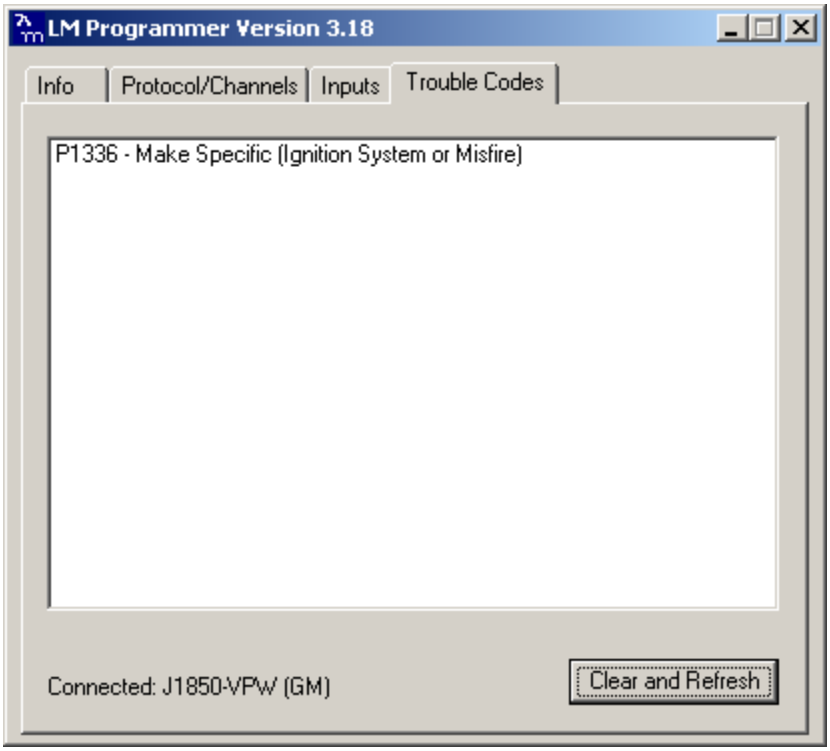
This extra resolution comes at the expense of our Low Priority inputs. These channels all share the ECU 'bandwidth' once used by VSS alone. But, this lets us have high resolution critical data combined with lower priority, lower resolution data in the same log.

3.6 Check and Clean Vehicle trouble Codes on the LM-2

1. To view your vehicle trouble codes press and hold the Mode button to go into the Configuration Menu Screen. Select OBD-II and press the Enter button.
2. Select Get DTC Codes. A list (if any) of error codes will be displayed on the screen. Click Mode or Cancel to exit.
3. To erase your vehicle trouble codes press and hold the Mode button to go into the Configuration Menu Screen. Select OBD-II and press the Enter button.
4. Select Clear DTC Codes and press the Enter button.

3.7 Check and Clear Vehicle Trouble Codes with LM Programmer

The last page in LM Programmer displays any Diagnostic Trouble Codes ("DTCs") currently reported by your vehicle. Like the Inputs page, the LM-2 must be connected to the ECU for this page to work correctly.



Standard Trouble Codes are listed both with a number and a description. Manufacturer specific codes will generally just appear as a number, though sometimes, like the case above, the general category can be identified.

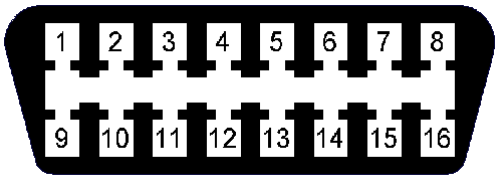
You can request that the ECU clear the pending codes using the Clear and Refresh button at the bottom right corner of the page.

Note: *On some vehicles, the ignition must be on, but the vehicle not started, for the Clear DTC request to be accepted.*

3.8 OBD II Basics

OBD stands for “On Board Diagnostics”. It represents a collection of industry and legislative standards for getting basic diagnostic information from passenger vehicles sold in the US since Model Year 1996. The “II” means that this is the second attempt at standardizing across all makes and models.

OBD-II standardized what type of information ECU’s must provide, but did not set a single standard on how the information should be communicated (typically called a ‘Communication Protocol’ or just ‘Protocol’) or even the electrical characteristics of the communication link itself (usually referred to as the ‘Physical Communication Link’). Instead, the various car manufacturers were each allowed to keep using their own existing protocols and physical links. We can see this compromise on the OBD-II connector itself:



Pin Assignments:

1. -
2. J1850+
3. -
4. Chassis Ground
5. Signal Ground
6. CAN (J2284) High
7. ISO 9141 K line
8. -
9. -
10. J1850-
11. -
12. -
13. -
14. CAN (J2284) Low
15. ISO 9141 L line
16. Battery Power

Note: Pins marked with ‘-‘ are sometimes used for make/model specific purposes.

Looking closely we can see that there are really three different electrical ‘pairs’, each representing a different type of physical communication link. J1850 (pins 2&10), CAN

(pins 6&14), and ISO (pins 7&15). On top of these three physical communication links are six different communication protocols:

- The J1850 pair uses either J1850pwm (Ford) or J1850vpw (GM)
- The CAN pair uses either 'standard' ISO 15765 or 'extended' ISO 15765
- The ISO pair use either ISO 9141 or ISO 14230 (sometimes referred to as KWP2000)

So, in order to get OBD-II information from any OBD-II compatible vehicle an interface needs to 'speak' six different languages over three different types of electrical links. Starting in MY2008, this will drop to one electrical link (CAN) and two protocol variations (ISO 15765 standard or extended) but that still leaves about 12 years of 'compromise' vehicles. Fortunately the LM-2 can take care of most of this complexity automatically. So, from a user's point of view OBD-II can primarily be considered on the basis of what is consistent and standard, namely:

- The Connector
- The Information Provided

OBD-II information comes in two basic flavors, "PIDs" and "DTCs". PIDs, or "Parameter IDs", represent real time measurements about the state of the power plant; information such as RPM and ignition timing. The definitive reference on these standard PIDs is the J1979 Standard (last revised 4/2002), published by the SAE International (www.sae.org). Not all ECUs support all PIDs, but the LM-2 understands and converts over 100 of the most common ones (see Appendix B for a complete list).

DTCs, or "Diagnostic Trouble Codes" are, as the name implies, problems reported by the ECU. Codes can be "Standard" or "Manufacturer Controlled". An example of a standard code would be P0051. This code means"HO2S Heater Control Circuit Low, Bank 2, Sensor 1" for all OBD-II vehicles. But P1336 is in the non-standard code range. The exact meaning is up to the vehicle maker. Without information from the car maker all we know from the code itself is that the beginning, P13xx, suggests that it is in the general category of "Ignition System or Misfire."

The definitive listing of standard DTCs is J2012 (last revised 4/2002), also published by SAE International. All these standard DTCs are reported as both a number and in plain English by the LM-2. Manufacturer Controlled DTCs are reported solely by number.

4 Analog Cable

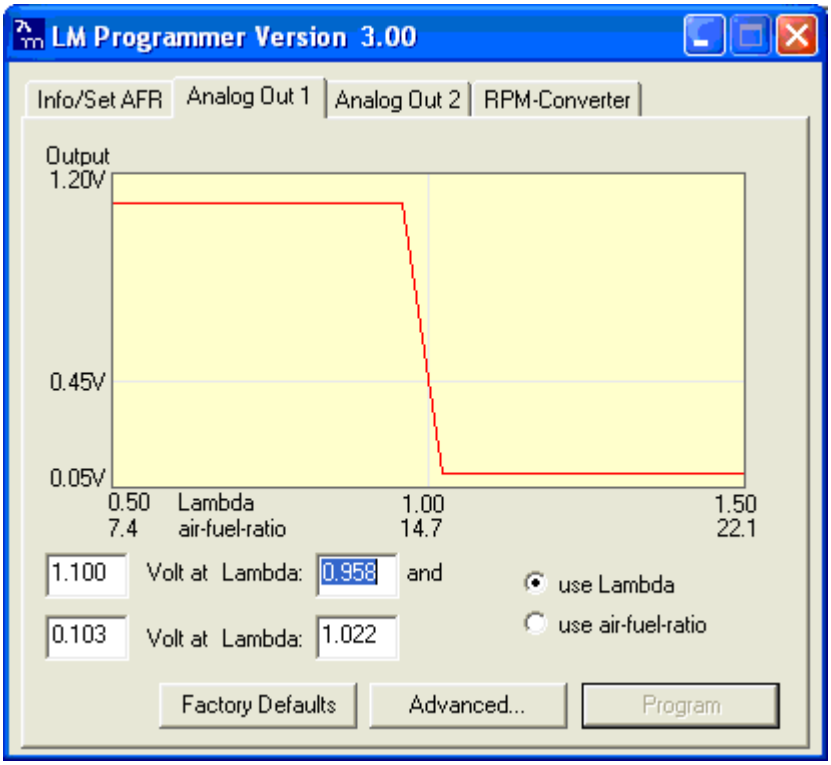
The provided analog cable has 14 stripped ends. The wire assignments are as follows:

Analog Out 1 + (Lime Green) Analog Out 1 – (Yellow)	Analog Out 2 + (Brown/White) Analog Out 2 – (Dark green)

Analog In 1 + (Purple) Analog In 1 – (Black)	Analog In 2 + (Grey) Analog In 2 – (Brown)
Analog In 3 + (White) Analog In 3 – (Red)	Analog In 4 + (Peach) Analog In 4 – (Orange)
RPM + (Black/White) RPM – (Blue)	

4.1. Programming the analog outputs

Select one of the Analog output tabs. The Analog output page looks like this:



This shows the analog output voltages versus Lambda for one of the two analog outputs. The graph display is automatically scaled to the selected voltages. For each output you can specify a minimum and maximum lambda value and the associated voltages. Below the minimum and above the maximum lambda values the output voltages stay constant at the associated programmed voltage.

By selecting the ‘use Air-Fuel-Ratio’ button you can program the curve by AFR instead of Lambda. This does not change the programming, only the representation of the data.

When programming by AFR the LM Programmer converts the number to Lambda before programming the LM-2.

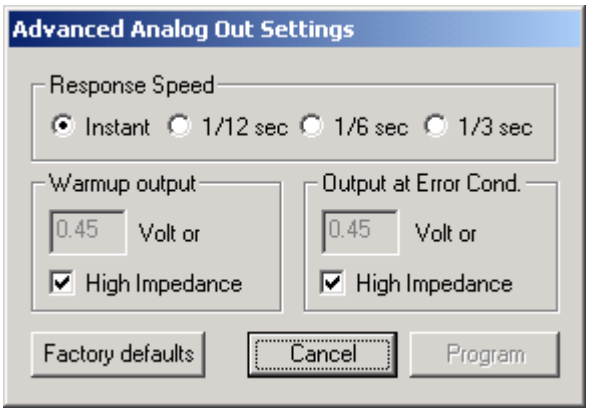
Click the Program button to download the new data into the LM-2.

Factory Programmed Defaults: The first output simulates a typical narrow band oxygen sensor. The second output is programmed to output between 0 V for an AFR of 7.35 (gasoline) and 5.0V for an AFR of 22.39. Other curves of course are easily programmable

4.1.1. *Advanced output programming*

The factory defaults of the analog outputs is to update the outputs every time the LM-2 takes a new measurement. The LM-2 is fast enough to distinguish individual pockets of exhaust gas. For many applications this will be too fast. The advanced programming allows the user to set the analog out update speed.

Press the “Advanced button” to set the advanced analog out settings. The following dialog box will appear:



When setting the LM-2 to the slower response speed settings the measured mixture data will be averaged over the response time setting before being output.

You can also specify what output voltage is visible on the analog outputs during warm-up of the sensor and during error conditions.

The ‘High Impedance’ setting allows the user to specify that the analog outputs do not drive the output during warm-up or error condition. They will be free floating. This is important for simulating a narrow band sensor. Many EFI systems monitor the impedance of a narrow band sensor during engine warm-up to determine sensor readiness. A narrow band sensor that’s too cold will have a high impedance.

5 Tips, Tricks, & Trouble Shooting

5.1 Air/Fuel and Lambda

The Stoichiometric AFR value is the AFR multiplier. So for (standard, unblended) gasoline its 14.7. If you set it to 14.7 the LM-2 display will show 14.7 AFR for Lambda 1.0. If you set it to 6.4 (methanol) the LM-2 will show 6.4 AFR for Lambda 1.0.
You can look at Lambda as the percent of richness. If running Lambda 0.85 (12.5 AFR for gasoline) you are running 15% rich. For methanol 15% rich means 5.44 AFR. That's where the value of Lambda comes in. If you run blended fuels where you don't know the stoich value, you look at Lambda and adjust to 10-20% rich, depending where your max power is. The % value of richness required by an engine (for max power) does change relatively little (fairly independent of fuel). But if for example you adjust an engine running methanol to 12.5 AFR, you would be running so lean that it would probably not even run.
The LM-2 can be used to read Air/Fuel Ratio (AFR) or Lambda for an engine. For *gasoline*-driven engines, the theoretically optimal air fuel ratio for efficiency is 14.7 pounds of air for every pound of fuel. At this ratio, theoretically, all available oxygen in the air combines with all available fuel. This ratio is called the stoichiometric ratio. Stoichiometric for different fuels are as follows:

Gasoline	14.7
LPG (Propane)	15.5
Methanol	6.4
Ethanol	9.0
CNG	17.2
Diesel	14.6

The measurement Lambda is the actual air fuel ratio over the stoichiometric ratio. A Lambda measurement of “1” equates to the air fuel ratio of 14.7 (for gasoline engines). When Lambda is less than 1 the engine runs “rich”, i.e., unburned fuel exists in the exhaust stream. If lambda is greater than 1 the engine runs lean, i.e., free oxygen (0^2) is present in the exhaust. Depending on the engine, maximum power is typically delivered when the engine runs slightly rich (for example at lambda values of 0.8 to 0.9 for most engines). This instrument provides a means to measure the actual air fuel ratio or lambda in the engine in operation directly from the exhaust. For this a special wide-band oxygen sensor is used to measure the lambda value derived from the oxygen content (or lack thereof) of the exhaust gases.

5.2 General measurement requirements

The LM-2 measures the air-fuel-ratio by measuring the amount of oxygen in the exhaust (for lean conditions) or the amount of unburned or partially burned fuel (for rich conditions). You should correct for the following in order to get optimum results from the LM-2

1) An exhaust leak will allow oxygen to enter the exhaust stream and therefore will measure leaner than the engine is actually running. For correct measurement, air-leaks in the exhaust MUST be prevented under all circumstances.
2) Missing ignitions (where the air-fuel mixture does not ignite) also pump unburned oxygen into the exhaust and cause the LM-2 to measure lean.
3) The only circumstance where the LM-2 will measure richer than the engine is running is if the pressure in the exhaust tract is excessive (and the engine is running on the rich side to begin with).

5.3 Vehicles with 'smog-pumps'

Older fuel injected vehicles with a 'smog-pump' actually inject air into the exhaust stream to aid their catalytic converter in the burn-up of unburned or partially burned fuels. This additional air will make the exhaust look leaner than the engine is running. For an accurate measure, install the LM-2 sensor up-stream of the outputs of the smog-pump. If this is not possible, temporarily disable the smog-pump by removing its drive belt.

5.4 Single Cylinder Engines

These kinds of engines are difficult to measure at the tail-pipe using an Exhaust Clamp. The oscillations of the exhaust gas are so large that a lot of outside air enters the exhaust and prevents correct measurement. Sometimes it helps to temporarily wrap a piece of heat resistant cloth around the exhaust clamp to prevent outside air from entering the exhaust.

5.5 Diesel Engines

Diesel Engines and gas turbines run at wide open throttle at all times. They do not have a throttle but regulate power by the amount of injected fuel. The LM-2 can still be used, but measurements at idle will read as lean.

5.6 Sensor Timing Errors

These errors are typically encountered when the sensor does not have outside air available as reference gas. If you encounter this error, restart the LM-2 and operate the sensor in free air (remove from exhaust.) If you still encounter this error, the sensor may be bad and needs to be replaced.

Replacement sensors are available from your nearest VW dealer under the VW part-number 021-906-262-B or direct from Innovate Motorsports (part number 3737.)

Sensor timing errors are also common when the sensor overheats. Relocate the sensor further downstream in the exhaust and/or install a Heat-Sink Bung extender (HBX-1). This problem is easier to diagnose as you will only see the error code come up at wide open throttle.

Sometimes it's possible to encounter Error 08 when the exhaust gas suddenly gets too rich.

5.7 Connecting the LM-2 to simulate a narrow band oxygen sensor.

It is possible to install the wide-band sensor in place of the OEM oxygen sensor. In this case the meter's analog output signal will replace the OEM oxygen sensor's signal to the fuel injection computer. EFI equipped cars typically incorporate a narrow band oxygen sensor. These sensors are typically 1, 2, 3 or 4 wire sensors.

The analog output connector of the LM-2 can simulate the operation of a narrow band sensor while the wide-band oxygen sensor is installed in place of the OEM narrow-band sensor. Factory equipped Analog output 1 of the LM-2 is programmed to simulate a narrow band sensor. Some vehicles are equipped with oxygen sensors that do not produce an output voltage but change their resistance depending on exhaust gas content. These sensors cannot be simulated. They are used in less than 1% of all vehicles. Refer to your vehicles specifications if you think that your vehicle may be in this category. The same is true for vehicles already factory equipped with a wide-band oxygen sensor. These cannot be simulated either.

Some EFI-computers will create a fault when the heater power wires of the oxygen sensor are disconnected. In this case mount the old oxygen sensor in a safe place (but not necessarily in the exhaust) and connect the heater wires to it to keep the EFI-computer happy.

Be careful where you mount the stock sensor, as heated sensors will get hot.

To connect the LM-2 to the EFI-computer, first determine what kind of narrow band sensor is used, then follow the instructions below (you will need a digital multimeter to determine correct OEM sensor wires):

a. Vehicle has a 1-wire sensor:
Wire analog output 1 directly to the wire.

b. Vehicle has a 2-wire sensor:
While the engine is off determine which of the 2 wires has a low resistance between the wire and the sensor body. This is the heater power for the sensor. Wire analog output 1 directly to the other wire. Leave the heater power wire unconnected but make sure it cannot ground itself.

c. Vehicle has a 3-wire sensor:
Typically the 3 wires are: heater power, Ground, and sensor element connection. Generally they have 1 black wire and 2 white wires. Connect the black wire from the EFI computer to analog output 1 of the meter. Leave the other wires unconnected but make sure they cannot contact any metal parts or see above. If the wiring colors are different, then heater power can simply be determined by measuring the voltage on the wires when the engine is running. The wire showing 12V or more is the heater power. The sensor element connection voltage fluctuates around 0.45V when the car is warmed up. Wire analog output 1 directly to this wire. The Ground connection has low resistance to chassis ground (less than 1 Ohm). Measure while the engine is off.

d. Vehicle has a 4-wire sensor
Typically the 4 wires are: heater power, heater ground, sensor ground, and sensor element connection. Proceed as for the 3-wire sensor.

Appendix A: Specifications

Power	
Power requirements	Single Channel 8-14 Volt / 2 A (max, 1 A nominal) Dual Channel 8-14 Volt / 4 A (max, 2 A nominal)
Serial Communication	
Serial Port Speed	19.2 kbit/sec
Packet/Logging Speed	81.92 msec/sample packet
Sample Resolution	10 bits (0..5V at 0.1% resolution)
Software	
Supported OSs	Windows 98, ME, 2000, XP, and Vista
OBD-II Specifications	
Number of Channels	16 (max)
Supported protocols	ISO 157650 (CAN), J1850PWM, J1850VPW, ISO 9141, ISO 14230 (KWP2000)
USB Specifications	
Protocol Version	2.0
Supported OSs	Windows 98, ME, 2000, XP, and Vista
Temperature	
Max Operating Temperature	-20 to +80 deg Celsius

Appendix B: Limited Warranty

LIMITED WARRANTY

Innovate stands behind the quality of its products. Innovate makes the following warranty to purchasers of its products: All new Innovate products carry a six-month warranty from the date of purchase. If proof of purchase cannot be provided, warranty will be determined by date of manufacture.

When Warranty Void

This warranty shall terminate and Innovate shall have no obligation pursuant to it if (i) your Innovate product has been modified or repaired in a manner not previously authorized by Innovate in writing, (ii) the identification markings on your Innovate product have been removed, defaced, or altered; (iii) your Innovate product was subjected to accident, abuse, shipping damage, or improper use; (iv) your Innovate product was not used or configured as specified in the product manual; or (v) your Innovate product was subjected to operating conditions more severe than those specified in the product manual.

Exclusions From This Warranty

Oxygen Sensors are excluded from this warranty.

Repairs Under This Warranty

In the unlikely event that your Innovate hardware product should prove defective during the warranty period, contact Innovate Customer Support for a return material authorization (RMA) at 949-502-8400. Products returned for service must be securely packed to prevent damage and shipped charges pre paid, along with proof of purchase and the return material authorization number, to the Innovate repair location as instructed by Customer Service. Innovate within a reasonable amount of time from its receipt of your product so shipped, will ship to you, at its option, the repaired product or a new or reconditioned product of comparable or greater specified functionality. All repaired or replacement products shall be warranted for the remainder of the original product warranty.

Disclaimer

INNOVATE MAKES NO OTHER EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO YOUR INNOVATE PRODUCT OTHER THAN THE LIMITED WARRANTY SET FORTH ABOVE. No Innovate dealer, agent, or employee is authorized to make any modification, extension, or addition to this warranty, unless enforceable or unlawful under applicable law, INNOVATE DISCLAIMS ALL IMPLIED WARRANTIES, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY, NONINFRINGEMENT, AND FITNESS FOR A PARTICULAR PURPOSE, AND THE LIABILITY OF INNOVATE, IF ANY, FOR DAMAGES RELATING TO ANY ALLEGEDLY DEFECTIVE PRODUCT SHALL UNDER ANY TORT, CONTRACT, OR OTHER LEGAL THEORY BE LIMITED TO THE ACTUAL PRICE PAID FOR SUCH PRODUCT AND SHALL IN NO EVENT INCLUDE INCIDENTAL, CONSEQUENTIAL, SPECIAL, OR INDIRECT DAMAGES OF ANY KIND EVEN IF INNOVATE IS AWARE OF THE POSSIBILITY OF SUCH DAMAGES. Some states do not allow limitations on how long an implied warranty lasts or the exclusion or limitation of incidental or consequential damages, so the above limitations or exclusions may not apply to you.

Appendix C: Connectors

1. Sensor 1 (2 optional)

Pin	Use
1	IPUMP+
2	SENSE/PUMP-
3	SHTR

4	VBAT
5	SENSE+
6	SHIELD GND
7	SHTR
8	VBAT

Tip: Sensor 1 is near the back of the unit and marked with a circled “1”

2. OBD-II

Pin	Use
1	GND
2	VBAT
3	J1850+
4	J1850-
5	ISO K
6	ISO L
7	CAN-H
8	CAN-L
9	Alt-CAN-H
10	Alt-CAN-L

Notes: The “Alt CAN” Buss is for instrument monitoring and is not connected to the J1962 connector in the standard Innovate Cable. Also, the unit can be powered via this connector for basic operation. However, the O2 sensor circuits are not powered when OBD-II is used as the power source. The O2 sensor(s) require the normal power connection.

3. Analog

Looking at the connector with the clip up, pin 1 is the lower left.

Pin	Use
1	Analog In 1 - Black
2	Analog In 2 - Brown
3	Analog In 3 - Red
4	Analog In 4 - Orange
5	Analog Out 1 - Yellow
6	Analog Out 2 – Dark green
7	RPM - Blue
8	Analog In 1 + - Purple
9	Analog In 2 + - Grey
10	Analog In 3 + - White
11	Analog In 4 + - Peach
12	Analog Out 1 + - Lime Green
13	Analog Out 2 + - Brown/White
14	RPM + - Black/White

Note: All these inputs and outputs are “differential”. That is, the negative inputs must be connected to ground.

4. Serial Out

Pin	Use
1	RX
2	TX
3	GND
4	GND

5. Serial In

Pin	Use
1	TX
2	RX
3	GND
4	*MTS Sense

6. Inductive Clamp

Pin	Use
1	Coil +
2	Coil –

7. USB

Pin	Use
1	NC
2	D-
3	D+
4	NC
5	GND

The unit CANNOT be powered from USB. It must be powered via OBD-II or the main power connector for use.

8. Power

Pin	Use
1,3	GND
2,4	VBAT

Appendix D: Supported PIDs

Name – Description	Units	Min.	Max
"RPM - Engine RPM",	"RPM",	0.0,	10230.0,
"TP - Throttle Position(abs)", "%",	0.0,	100.0,	
"LOAD_PCT - Engine Load(calc)",	"%",	0.0,	100.0,
"SPARKADV - Timing Advance(cyl1)",	"degBTDC",	-64.0,	63.5,
"MAF - Mass Air Flow",	"g/s",	0.0,	655.35,
"MAP - Manifold Abs. Presure",	"kPa",	0.0,	255.0,
"VSS - Vehicle Speed Sensor",	"km/h",	0.0,	255.0,

"ECT - Engine Coolant Temp",		"degC",	-40.0,		215.0,
"IAT - Intake Air Temp",	"degC",		-40.0,	215.0,	
"PTO_STAT - PTO Status",	"PTO",		0.0,	1.0,	
"FUEL1_OL - Fuel Sys1 Open Loop",	"OL",		0.0,	1.0,	
"FUEL2_OL - Fuel Sys2 Open Loop",	"OL",		0.0,	1.0,	
"SHRTFT1 - Short Term Fuel Trim 1",	"%",		-100.0,	99.22,	
"LONGFT1 - Long Term Fuel Trim 1",	"%",		-100.0,	99.22,	
"SHRTFT2 - Short Term Fuel Trim 2",	"%",		-100.0,	99.22,	
"LONGFT2 - Long Term Fuel Trim 2",	"%",		-100.0,	99.22,	
"SHRTFT3 - Short Term Fuel Trim 3",	"%",		-100.0,	99.22,	
"LONGFT3 - Long Term Fuel Trim 3",	"%",		-100.0,	99.22,	
"SHRTFT4 - Short Term Fuel Trim 4",	"%",		-100.0,	99.22,	
"LONGFT4 - Long Term Fuel Trim 4",	"%",		-100.0,	99.22,	
"FRP - Fuel Rail Pressure",	"kPa",		0.0,	765.0,	
"FRP_MED - Fuel Rail Pressure",	"kPa",		0.0,	5177.27,	
"FRP_HIGH - Fuel Rail Pressure",	"kPa",		0.0,	655350.0,	
"EQ_RAT - Commanded Equiv. Ratio",	"lambda",	0.0,		1.999,	
"LOAD_ABS - Absolute Load Value",	"%",		0.0,	802.75,	
"EGR_PCT - Commanded EGR",		"%",	0.0,		100.0,
"EGR_ERR - EGR Error",		"%",	-100.0,		99.22,
"TP_R - Throttle Position(rel)","%",		0.0,		100.0,	
"TP_B - Throttle Position B(abs)",	"%",		0.0,	100.0,	
"TP_C - Throttle Position C(abs)",	"%",		0.0,	100.0,	
"APP_D - Acc. Pedal Position D",	"%",		0.0,	100.0,	
"APP_E - Acc. Pedal Position D",	"%",		0.0,	100.0,	
"APP_F - Acc. Pedal Position D",	"%",		0.0,	100.0,	
"TAC_PCT - Commanded Throttle",	"%",		0.0,	100.0,	
"EVAP_PCT - Commanded Evap. Purge",		"%",	0.0,		100.0,
"EVAP_VP - Evap. Vapor Pressure",	"Pa",		-8192.0,	8191.0,	
"AIR_UPS - Secondary Air DNS",	"UPS",		0.0,	1.0,	
"AIR_DNS - Secondary Air DNS",	"DNS",		0.0,	1.0,	
"AIR_OFF - Secondary Air DNS",	"OFF",		0.0,	1.0,	
"FLI - Fuel Level Indicator",	"%",		0.0,	100.0,	
"BARO - Barometric Pressure",		"kPa",	0.0,		255.0,
"AAT - Ambient Air Temp",	"degC",		-40.0,	215.0,	
"VPWR - Control Module Voltage",	"Volts",	0.0,		65.535,	
"MIL - Malfunction Indicator Lamp",	"MIL",		0.0,	1.0,	
"DTC_CNT - DTC Count",		"DTCs",	0.0,		1023.0,
"MIL_DIST - Distance MIL active",	"km",		0.0,	65535.0,	
"MIL_TIME - Hours MIL active",	"hours",	0.0,		1023.0,	
"CLR_DIST - Distance MIL clear",	"km",		0.0,	65535.0,	
"WARM_UPS - Warm Ups MIL clear",	"WUs",		0.0,	1023.0,	
"RUNTM - Run Time",		"mins",	0.0,		1023.0,
"O2S11 - O2 Sensor(NB) 1-1",		"Volts",	0.0,	1.275,	
"SHRTFT11 - O2 Fuel Trim 1-1",	"%",		-100.0,	99.22,	
"O2S12 - O2 Sensor(NB) 1-2",		"Volts",	0.0,	1.275,	
"SHRTFT12 - O2 Fuel Trim 1-2",	"%",		-100.0,	99.22,	
"O2S21 - O2 Sensor(NB) 2-1",		"Volts",	0.0,	1.275,	
"SHRTFT21 - O2 Fuel Trim 2-1",	"%",		-100.0,	99.22,	
"O2S22 - O2 Sensor(NB) 2-2",		"Volts",	0.0,	1.275,	
"SHRTFT22 - O2 Fuel Trim 2-2",	"%",		-100.0,	99.22,	
"O2S31 - O2 Sensor(NB) 3-1",		"Volts",	0.0,	1.275,	
"SHRTFT31 - O2 Fuel Trim 3-1",	"%",		-100.0,	99.22,	
"O2S32 - O2 Sensor(NB) 3-2",		"Volts",	0.0,	1.275,	
"SHRTFT32 - O2 Fuel Trim 3-2",	"%",		-100.0,	99.22,	
"O2S41 - O2 Sensor(NB) 4-1",		"Volts",	0.0,	1.275,	
"SHRTFT41 - O2 Fuel Trim 4-1",	"%",		-100.0,	99.22,	
"O2S42 - O2 Sensor(NB) 4-2",		"Volts",	0.0,	1.275,	
"SHRTFT42 - O2 Fuel Trim 4-2",	"%",		-100.0,	99.22,	
"EQ_RAT11 - WideO2 Equiv-Ratio 1-1",	"lambda",	0.0,		1.999,	
"WO2S11 - WideO2 Voltage 1-1",	"Volts",	0.0,		7.999,	
"EQ_RAT12 - WideO2 Equiv-Ratio 1-2",	"lambda",	0.0,		1.999,	
"WO2S12 - WideO2 Voltage 1-2",	"Volts",	0.0,		7.999,	
"EQ_RAT21 - WideO2 Equiv-Ratio 2-1",	"lambda",	0.0,		1.999,	
"WO2S21 - WideO2 Voltage 2-1",	"Volts",	0.0,		7.999,	
Name – Description	Units		Min.		Max
"EQ_RAT22 - WideO2 Equiv-Ratio 2-2",	"lambda",	0.0,		1.999,	
"WO2S22 - WideO2 Voltage 2-2",	"Volts",	0.0,		7.999,	
"EQ_RAT31 - WideO2 Equiv-Ratio 3-1",	"lambda",	0.0,		1.999,	

```
"WO2S31 - WideO2 Voltage 3-1",          "Volts",    0.0,                 7.999,
"EQ_RAT32 - WideO2 Equiv-Ratio 3-2", "lambda", 0.0,                 1.999,
"WO2S32 - WideO2 Voltage 3-2",          "Volts",    0.0,                 7.999,
"EQ_RAT41 - WideO2 Equiv-Ratio 4-1", "lambda", 0.0,                 1.999,
"WO2S41 - WideO2 Voltage 4-1",          "Volts",    0.0,                 7.999,
"EQ_RAT42 - WideO2 Equiv-Ratio 4-2", "lambda", 0.0,                 1.999,
"WO2S42 - WideO2 Voltage 4-2",          "Volts",    0.0,                 7.999,
"WBEQ_RAT11 - WB-O2 Equiv-Ratio 1-1",          "lambda", 0.0,                 1.999,
"WBO2S11 - WB-O2 Voltage 1-1",          "mA",               -128.0,            127.996,
"WBEQ_RAT12 - WB-O2 Equiv-Ratio 1-2",          "lambda", 0.0,                 1.999,
"WBO2S12 - WB-O2 Voltage 1-2",          "mA",               -128.0,            127.996,
"WBEQ_RAT21 - WB-O2 Equiv-Ratio 2-1",          "lambda", 0.0,                 1.999,
"WBO2S21 - WB-O2 Voltage 2-1",          "mA",               -128.0,            127.996,
"WBEQ_RAT22 - WB-O2 Equiv-Ratio 2-2",          "lambda", 0.0,                 1.999,
"WBO2S22 - WB-O2 Voltage 2-2",          "mA",               -128.0,            127.996,
"WBEQ_RAT31 - WB-O2 Equiv-Ratio 3-1",          "lambda", 0.0,                 1.999,
"WBO2S31 - WB-O2 Voltage 3-1",          "mA",               -128.0,            127.996,
"WBEQ_RAT32 - WB-O2 Equiv-Ratio 3-2",          "lambda", 0.0,                 1.999,
"WBO2S32 - WB-O2 Voltage 3-2",          "mA",               -128.0,            127.996,
"WBEQ_RAT41 - WB-O2 Equiv-Ratio 4-1",          "lambda", 0.0,                 1.999,
"WBO2S41 - WB-O2 Voltage 4-1",          "mA",               -128.0,            127.996,
"WBEQ_RAT42 - WB-O2 Equiv-Ratio 4-2",          "lambda", 0.0,                 1.999,
"WBO2S42 - WB-O2 Voltage 4-2",          "mA",               -128.0,            127.996,
"CATEMP11 - Catalyst Temp 1-1",         "degC",             -40.0,             6513.5,
"CATEMP21 - Catalyst Temp 2-1",         "degC",             -40.0,             6513.5,
"CATEMP12 - Catalyst Temp 1-2",         "degC",             -40.0,             6513.5,
"CATEMP22 - Catalyst Temp 2-2",         "degC",             -40.0,             6513.5,
```

Appendix E: Error Codes and Troubleshooting Tips

Error Code	Error Message	Likely Root Cause	Fix
Error 1	Heater circuit shorted	1. Short in cable 2. Short in sensor	1. Repair/replace cable. 2. Replace sensor.
Error 2	Heater circuit open	1. Damaged sensor cable or Cable connector not fully seated	1. Verify Sensor connector is fully seated into unit. Repair/replace Sensor or cable.
Error 3	Pump cell circuit shorted	1. Short in sensor cable 2. Short in sensor 3. Sensor heater calibration incorrect 4. Sensor overheating 5. EGT >1700º F	1. Repair sensor cable. 2. Replace sensor. 3. Perform sensor heater recalibration. 4. Move your sensor bung as far downstream as possible OR add a heatsink to isolate the sensor from the pipe.
Error 4	Pump cell circuit open	1. Damaged sensor cable or sensor connector not fully seated 2. Sensor heater calibration incorrect	1. Verify sensor connector is fully seated into unit. Repair/replace cable. 2. Perform complete heater calibration (not just free air calibration). See section 4
Error 5	Reference cell circuit shorted	1. Short in sensor cable 2. Short in sensor	1. Repair sensor cable. 2. Replace sensor.
Error 6	Reference cell circuit open	1. Damaged sensor cable or sensor connector not fully seated 2. Damaged Sensor	1. Verify sensor connector is fully seated into unit. 2. Replace sensor
Error 7	General System error (typically a software error).	Typically a software error	Reboot LM-2 by cycling power. Re-flash unit if necessary.
Error 8	Sensor Timing error (typically a damaged sensor).	1. Sensor overheating. (The Bosch LSU4.2 is rated to operate at a sensor housing temperature of < 900 degrees (measured at the bung) for maximum accuracy and control. When this operating	1. a. Perform sensor heater recalibration; b. Move your sensor bung as far downstream as possible. Right before the cat, or 2-3 feet from the end of the tailpipe are good locations; c. Add a heatsink to isolate the

		temperature range is exceeded, the sensor can no longer be accurately controlled.) 2. Sensor is damaged 3. Overly Rich condition	sensor from the pipe. The HBX-1 is an available accessory. 2. Replace sensor. 3. Correct Tune and recalibrate the sensor.
Error 9	Supply Voltage too low	Supply voltage too low for sensor regulation	Check your 12V connection for corrosion.

6 Revision History

1.0 6/23/2008
Initial Release